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AGRICULTURAL MEMORANDUM No 1088

FURTHER INVESTIGATIONS INTO THE EFFECTS OF ENVIRONMENTAL CHANGES ON HERBAGE WATER SOLUBLE CARBOHYDRATE LEVELS.

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Summary

Changes in the water soluble carbohydrate (WSC) level of Italian ryegrass over periods of 3, 7 and 14 days, based on measurements made at twice-weekly intervals (during the spring of 1986), were regressed against changes in mean daily solar radiation, mean daily sunshine and mean temperature over similar periods, and accumulated temperatures above 6°C from 1 April. Good correlations were obtained between WSC changes and changes in mean daily solar radiation over all 3 periods. Correlations for 7 and 14 day periods were improved when mean temperature changes and accumulated temperature were also included in the regressions. The use of mean daily sunshine instead of solar radiation gave acceptable results in most cases.

Introduction

Agricultural Memorandum 1031 described the effect of environmental changes on the WSC content of early perennial ryegrass. The analysis was based on sample data collected weekly by the ADAS Herbage Quality Monitoring Survey (HQM), and regressions were derived for changes in WSC content against changes in mean daily sunshine and temperature over 7 and 14 day periods.

During the spring of 1986 herbage samples were collected twice weekly from a HQM sample site about 10 km NE of Westbury-on-Trym in order to investigate shorter term variations in WSC content with changes in weather.

Data

Herbage samples were taken twice weekly (usually on Mondays and Thursdays) from a commercial Italian ryegrass crop being used for silage and were analysed for WSC content (20% DM), D value and dry matter content in the Nutrition Chemistry Dept at Bristol.

Meteorological data were used from several sources. Daily maximum and minimum temperatures and solar radiation totals were measured on the meteorological site at Westbury-on-Trym, and daily sunshine totals were those recorded at Bristol Weather Centre. A daily water balance for the site was calculated for the period over which sampling took place using actual evapotranspiration for MORECS square 157 and rainfall figures from the nearest rain-gauge site (about 4 km SE of the sample site). Accumulated temperatures were calculated using daily maximum and minimum temperatures for Westbury-on-Trym, and were summed above a base of 6°C from 1 April.

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Analysis and Results

Changes in WSC content were calculated for 3, 7 and 14 day periods. Changes in mean temperature, mean daily solar radiation and sunshine hours were calculated over the same periods, together with the change in soil moisture deficit between sampling dates. The accumulated temperature above 6°C was also calculated from 1 April to each sample date. Changes in WSC content over 3, 7 and 14 day periods were then regressed against changes in meteorological variables over corresponding periods.

i. Solar radiation(R)/sunshine(S) ($MJm^{-2}day^{-1}$/hrs day^{-1})

Change in WSC content was highly correlated with change in mean daily solar radiation for all three time periods, but the best correlation was obtained for 3 day changes ($r = 0.82$). A good correlation was also obtained when mean daily sunshine was used in place of mean daily solar radiation ($r = 0.79$ for 3 day changes).

a) 3 day - using radiation $\Delta WSC = -0.03 + 0.14\Delta R$
($P < 0.0001$, $r = 0.82$, RMSE = 0.47)
- using sunshine $\Delta WSC = -0.03 + 0.23\Delta S$
($P < 0.0005$, $r = 0.79$, RMSE = 0.51)

b) 7 day - using radiation $\Delta WSC = -0.09 + 0.18\Delta R$
($P < 0.01$, $r = 0.66$, RMSE = 0.73)
- using sunshine $\Delta WSC = -0.06 + 0.26\Delta S$
($P < 0.005$, $r = 0.69$, RMSE = 0.70)

c) 14 day - using radiation $\Delta WSC = -0.35 + 0.28\Delta R$
($P < 0.025$, $r = 0.64$, RMSE = 0.73)
- using sunshine $\Delta WSC = -0.08 + 0.30\Delta S$
($P < 0.05$, $r = 0.57$, RMSE = 0.78)

The number of data points used to derive equations a), b) and c) was 16, 15 and 14 respectively.

ii. Solar radiation(R)/sunshine(S) and temperature(T) (°C)

Correlations between WSC changes and temperature changes alone were not significant over any of the three time periods. When solar radiation changes were also included in a multiple regression against WSC changes correlations were similar to those obtained using solar radiation changes only. The use of the sunshine changes in place of solar radiation changes gave poorer correlation coefficients, and the regression obtained for 14 day changes was not significant.

a) 3 day - using radiation $\Delta WSC = -0.02 + 0.14\Delta R - 0.03\Delta T$
($P < 0.001$, $r = 0.82$, RMSE = 0.49)
- using sunshine $\Delta WSC = -0.03 + 0.23\Delta S + 0.01\Delta T$
($P < 0.005$, $r = 0.79$, RMSE = 0.53)

b) 7 day - using radiation $\Delta WSC = 0.03 + 0.16\Delta R - 0.14\Delta T$
($P < 0.025$, $r = 0.69$, RMSE = 0.74)
- using sunshine $\Delta WSC = 0.05 + 0.23\Delta S - 0.12\Delta T$
($P < 0.025$, $r = 0.71$, RMSE = 0.71)

c) 14 day - using radiation $\Delta WSC = -0.26 + 0.29\Delta R - 0.05\Delta T$
($P < 0.05$, $r = 0.65$, RMSE = 0.76)
- using sunshine $\Delta WSC = -0.07 + 0.30\Delta S - 0.01\Delta T$
(P not sig, $r = 0.57$, RMSE = 0.82)

The number of data points used was the same as for equations i(a), i(b) and i(c).

iii. Solar radiation(R)/sunshine(S) and accumulated temperature(AT) ($^{\circ}$ days)

The inclusion of accumulated temperature (as a measure of phenological development) in place of temperature improved the correlation and reduced the RMS error over all 3 time periods when using solar radiation, and over 3 and 7 day periods when using sunshine. Over 3 days and 14 days, solar radiation gave a slightly more significant regression than sunshine, with smaller RMS errors.

a) 3 day - using radiation $\Delta WSC = 0.41 + 0.14\Delta R - 0.002$ AT
($P < 0.0005$, $r = 0.86$, RMSE = 0.44)
- using sunshine $\Delta WSC = 0.34 + 0.22\Delta S - 0.0017$ AT
($P < 0.001$, $r = 0.81$, RMSE = 0.50)

b) 7 day - using radiation $\Delta WSC = 0.62 + 0.17\Delta R - 0.0031$ AT
($P < 0.025$, $r = 0.73$, RMSE = 0.69)
- using sunshine $\Delta WSC = 0.59 + 0.24\Delta S - 0.0028$ AT
($P < 0.01$, $r = 0.74$, RMSE = 0.67)

c) 14 day - using radiation $\Delta WSC = 0.29 + 0.23\Delta R - 0.0023$ AT
($P < 0.05$, $r = 0.67$, RMSE = 0.74)
- using sunshine $\Delta WSC = 0.77 + 0.22\Delta S - 0.0034$ AT
($P < 0.1$, $r = 0.63$, RMSE = 0.77)

The number of data points used was the same as for equations i(a), i(b) and i(c).

iv. Solar radiation(R)/sunshine(S), temperature(T) and accumulated temperature(AT)

Including both temperature changes and accumulated temperatures as well as solar radiation/sunshine changes in the regressions did not give any improvement on regression iii(a) for 3 day changes, but did give a substantial improvement over both 7 and 14 days.

a) 3 day - using radiation $\Delta WSC = 0.37 + 0.14\Delta R - 0.05\Delta T - 0.002$ AT
($P < 0.001$, $r = 0.86$, RMSE = 0.46)
- using sunshine $\Delta WSC = 0.34 + 0.22\Delta S - 0.002\Delta T - 0.002$ AT
($P < 0.005$, $r = 0.81$, RMSE = 0.52)

b) 7 day - using radiation $\Delta WSC = 1.59 + 0.11\Delta R - 0.38\Delta T - 0.006\ AT$
$(P < 0.005,\ r = 0.84,\ RMSE = 0.58)$

- using sunshine $\Delta WSC = 1.53 + 0.15\Delta S - 0.36\Delta T - 0.006\ AT$
$(P < 0.005,\ r = 0.84,\ RMSE = 0.58)$

c) 14 day - using radiation $\Delta WSC = 4.36 + 0.08\Delta R - 0.64\Delta T - 0.013\ AT$
$(P < 0.01,\ r = 0.82,\ RMSE = 0.59)$

- using sunshine $\Delta WSC = 4.77 + 0.05\Delta S - 0.67\Delta T - 0.014\ AT$
$(P < 0.01,\ r = 0.82,\ RMSE = 0.60)$

The use of sunshine changes in place of solar radiation changes did not reduce the significance of the regressions over 7 and 14 day periods, but did lead to a small reduction in the level of significance over 3 days and a change in the value of r from 0.86 to 0.81 (equation iv(a)).

v. Use of different time periods for different variables

By correlating changes in WSC content against changes in the values of each variable for each of the three time periods, it was possible to identify the time period over which WSC change was most sensitive for each variable. For solar radiation/sunshine this period was 3 days, whereas for temperature it was 7 days. 3 day WSC changes (WSC_3) were regressed against 3 day solar radiation changes (R_3), 7 day temperature changes (T_7) and accumulated temperature (AT), and the following regression was obtained:-

a) $\Delta WSC_3 = 0.97 + 0.14\Delta R_3 - 0.22\Delta T_7 - 0.0036\ AT$
$(P < 0.0001,\ r^2 = 0.92,\ RMSE = 0.36)$

The use of temperature changes over 7 days rather than 3 days increased P, the level of significance, from <0.1% to <0.01%, the correlation coefficient, r, from 0.86 to 0.92, and reduced the RMS error from 0.46 to 0.36 (see equation iv(a)). Similarly, the use of radiation changes over 3 days rather than 7 days increased P from <0.5% to <0.01%, r from 0.84 to 0.92 and reduced the RMS error from 0.58 to 0.36 (see equation iv(b)).

vi. Best equations for each time period

3 days

Over 3 day periods equation iii(a) best fitted the data. This used changes in mean daily solar radiation and accumulated temperatures above $6^{\circ}C$ (from 1 April) as variables, gave a correlation of 0.86, was significant at better than 0.05% level, and had RMSE of 0.44.

7 days

Over 7 day periods equation iv(b) gave the best fit, using changes in mean daily solar radiation, changes in mean temperature, and temperature accumulation above $6^{\circ}C$ as variables. The regression gave a correlation of 0.84, was significant at better than 0.5% level, and had a RMSE of 0.58.

14 days

The best fit over 14 day periods was obtained with equation iv(c) using the same variables as equation iv(b). A correlation of 0.82 was obtained, and the regression was significant at better than 1% level with a RMSE of 0.59.

For equations iv(b) and iv(c), the substitution of mean daily sunshine for mean daily solar radiation did not reduce the correlation coefficient or the significance level.

Conclusions

Although the format of the analysis carried out in this paper is similar to that used in Agricultural Memorandum 1031, there are significant differences in the data used and the results obtained. The data used differed in several respects: firstly, herbage sampling was carried out twice instead of once per week; secondly, solar radiation was used as a variable in place of sunshine; and finally accumulated temperature was also included as an additional variable. A further difference also lay in the type of grass used - in this case Italian ryegrass was used instead of early perennial ryegrass.

There are also several important differences between the results obtained from the two analyses. Firstly, it was thought that mean daily solar radiation would prove a better predictor of herbage WSC levels than mean daily sunshine. This was true to a limited extent for 3 day and 14 day changes (equation i(a) and (c)), but the improvement in the correlation coefficients and the reduction in the RMS errors was small.

The second important difference was the greater dependence of WSC changes on solar radiation/sunshine changes than was found in Agric Memo 1031. However, it was noted in Agric Memo 1031 that the influence of changes in sunshine hours was very much greater for occasions with temperature accumulations greater than 300 degree days than for occasions prior to this. The dependence of WSC changes on temperature changes was less marked in this analysis than was observed in Agric Memo 1031, particularly over 14 day periods where a significant regression could not be obtained using sunshine and temperature changes (see equation ii(c)). This difference in the balance between the responses to temperature and sunshine may reflect the "earliness" of IRG compared to early perennial ryegrass (on which the analysis in Agric Memo 1031 was based).

Finally, it is interesting to note that the RMS errors for equations ii(b) and (c) (0.71 and 0.82) are rather less than for the similar equations in Agric Memo 1031 (0.6 to 1.5), which are based on the same variables, but were derived from data for 8 different seasons (1977-84). Since the data used in this memorandum covered only one season, this suggests that the response of WSC changes to environmental changes varies from season to season. One possible explanation of this could be the effect of variations in soil moisture status between seasons. The effect of water stress on WSC levels was not investigated in this analysis since soil moisture deficits were small throughout the sampling period. However, during a dry spring it is likely that water stress will have an important influence on WSC levels.

By combining temperature changes over 7 days with solar radiation changes over 3 days the best regression was obtained for predicting 3 day changes in WSC

content (equation v(a)). This would suggest that the crop responds at a different rate to temperature changes than to solar radiation changes.

Accumulated temperature was incorporated as an additional variable in equation (iii) and (iv). Equations iv(b) and (c), using solar radiation/sunshine, temperature and accumulated temperature gave the best results over 7 and 14 days with the highest levels of significance and correlation and the smallest errors.

Acknowledgements

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Reference

RUMNEY, R.P. The effect of environmental changes on the water soluble carbohydrate content of early perennial ryegrass. Agricultural Memorandum 1031, Meteorological Office. (Unpublished paper available from Agromet Department).

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